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Water Resource Management Plan 2019

31 October 2018

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Company Headroom Analysis

Water Resource Management Plan 2019

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Executive summary

This document summarises the target headroom assessment carried out for the Company Water Resource Zone, forming part of the South Staffs Water WRMP19 planning process.

Target Headroom is defined as the minimum buffer that a prudent water utility should introduce into the annual supply-demand balance to ensure that the Water Utility's chosen level of service can be achieved. Target Headroom is calculated according to a standard methodology developed and published by UKWIR (An Improved Methodology for Assessing Headroom, UKWIR, 2002). All components of target headroom uncertainty have been assessed and reviewed by South Staffs Water, with time series of uncertainty distributions defined from 2018 to 2045 for each component, reflective of dry year annual average (DYAA) and dry year critical period (DYCP) conditions.

The distributions were uploaded into a tailor-made spreadsheet headroom model using @Risk Monte Carlo analysis. 10,000 iterations of the model were run to determine a comprehensive percentile distribution of headroom time series for both DYAA and DYCP conditions. A risk profile was selected in line with the WRMP guidelines and used to output target headroom values for supply demand balance modelling of the Water Resource Zone.

DYAA Target headroom starts at 7.0 MI/d in 2018, increasing steadily along the 95th percentile profile to a maximum of 9.9 MI/d in 2030. The increase in risk acceptance beyond 2030 means that target headroom decreases slowly thereafter to 7.8 MI/d by 2045. DYCP Target headroom starts at 11.6 MI/d in 2018, increasing steadily along the 95th percentile profile to a maximum of 13.7 MI/d in 2030. The increase in risk acceptance beyond 2030 means that target headroom fluctuates slightly thereafter, finishing at 12.8 MI/d by 2045.

1 Introduction and background

Water Companies in England and Wales have a statutory duty to prepare and submit Water Resources Management Plans (WRMP), including Supply Demand Balance (SDB), to the Environment Agency (EA) and Ofwat. A key component of these WRMPs is Target Headroom.

Target Headroom is defined as the minimum buffer that a prudent water utility should introduce into the annual supply-demand balance to ensure that the Water Utility's chosen level of service can be achieved. Target Headroom is calculated according to a standard methodology developed and published by UKWIR (An Improved Methodology for Assessing Headroom, UKWIR, 2002).

Mott MacDonald (MM) has been engaged by South Staffordshire Water to assess Target Headroom for the 2017 Draft WRMP.

1.1 Objectives and scope of work

The objectives of the project are:

- to review and analyse data provided by South Staffordshire Water, to evaluate uncertainty in headroom components and produce appropriate probability distributions for each component; and
- to assess South Staffordshire Water's Target Headroom under average and peak conditions.

In addition, the scope of work includes the actions below:

1. Update the analysis for uncertainty of impacts of climate change on demand;
2. Review the uncertainty in deployable output associated with changing nitrate concentration and make recommendation for an appropriate headroom allowance
3. Produce summaries of the headroom results by component;
4. Produce a report outlining the methodology and assumptions used and presenting the results of the analysis.

1.2 Background to Target Headroom

1.2.1 Why assess Target Headroom

A variety of components of the supply/demand balance are subject to uncertainty, both their present values and forecast future trends.

It is therefore important that water companies make sufficient allowance in their water resource planning for such uncertainty to ensure that, for each resource zone, the risk of a supply-demand deficit in critical periods is eliminated or reduced to an acceptable level. This is done by calculating and incorporating in the supply-demand balance a target headroom allowance.

Water companies must show evidence that they have taken this into account when they submit their WRMPs as part of the periodic review process. The last WRMPs were submitted to the Environment Agency in 2014 and 2015 and these also formed the companies' supply-demand balance submissions to the Office of Water Services (Ofwat) as part of PR14. These plans take a long-term view and demonstrate how the company intends to maintain an acceptable balance of supply and demand into the future. The last plans considered the planning period 2012 to 2040 whilst the PR19 planning period will cover the years 2017 to 2045.

1.2.2 Headroom in the Supply Demand Balance and Accepted Definitions

The Supply Demand Balance is calculated as the difference between Water Available for Use (including imported water if applicable) and demand at any given point in time by comparing deployable output (D.O.) with water demand, after allowing for outage and target headroom.

In assessing the supply demand balance, the following equations are normally adopted:

1. Water Available for Use (WAFU) = Deployable Output (DO) – Outage
2. Available Headroom = WAFU – demand
3. Available Headroom ≥ Target Headroom needed to satisfy given standards of service

Definitions for the terms used in the equations are given in Box 1 below. These are taken from the Environment Agency Water Resources Planning Guidelines (2012), and may vary slightly from other references. No change to definition is presented in the 2016 guidelines.

Table 1: Definitions

| Quantity | Definition |
|-------------------------|--|
| Water Available for Use | The value calculated by deducting allowable outages and planning allowances from deployable output in a resource zone |
| Available Headroom | The difference (in MI/d or percent) between water available for use (including imported water) and demand at any given point in time |
| Target Headroom | A buffer between supply and demand designed to cater for specified uncertainties. |

Source: EA Water Resource Planning Guidelines, June 2012

Deployable Output is generally considered to be the output of a source allowing for all constraints, whether physical, licence or environmental, for a given level of service. As such it is the volume of water that can be deployed into supply. Outage is defined at its simplest as a temporary loss of deployable output.

Target Headroom is defined as the minimum buffer that a prudent water utility should introduce into the annual supply-demand balance to ensure that the water utility's chosen level of service can be achieved. It is the margin between water available for use (WAFU) and demand required for planning purposes to cater for uncertainties (except for those due to outages) in the overall supply-demand balance.

Available Headroom is defined as the margin between Water Available for Use (WAFU) and demand at a given point in time and in theory is a measurable quantity of water. Target Headroom is a derived value which represents the minimum acceptable Headroom required for planning purposes to cater for uncertainties (excluding outages) in the overall supply-demand balance.

The issue of headroom came to prominence as a result of the 1995/96 Yorkshire drought where the independent commission of inquiry chaired by Professor Uff concluded that the Yorkshire Water supply system had an insufficient margin of resource over demand. This led to the concept of headroom uncertainty being introduced in the Environment Agency (EA) 1997 Water Resources Planning Guideline and the United Kingdom Water Industry Research (UKWIR) project that developed the 1998 Headroom Methodology. In 2002, UKWIR issued an improved risk based methodology for assessing headroom uncertainty (the 2002 UKWIR Headroom Methodology) which has been widely adopted and is considered to be the “best practice” methodology.

1.3 Environment Agency Water Resources Planning Guidance

The Environment Agency issued in May 2016 the Water Resource Planning Guidelines for the 2018 Water Resource Plans. The report states the following.

You may assess individual components of uncertainty and variability using risk-based planning techniques, through your decision-making tool or assess uncertainty separately from individual components using the target headroom approach. The following documents set out different approaches to assessing uncertainty:

- *UKWIR (2016) WRMP19 Methods – Risk Based Planning*
- *UKWIR (2016) WRMP19 Methods – Decision Making Process*
- *UKWIR (2002) An Improved Methodology for Assessing Headroom*
- *UKWIR (1998) A Practical Method for Converting Uncertainty into Headroom*

If you use the older target headroom guidance you should justify why it is appropriate.

If you use risk-based planning tools or a decision-making tool to assess uncertainty and variability you may not need to calculate target headroom, or you may need to exclude some target headroom components. If so, you will need to explain the methods and assumptions you have used and demonstrate that you have not double counted or omitted uncertainties.

If you use target headroom to provide a buffer for uncertainties, you need to consider the appropriate level of risk for your plan. If target headroom is too large it may drive unnecessary expenditure, if too little you may be unable to meet your planned level of service. You should also accept a higher level of risk further into future than in the early years (first 5 years) because as time progresses the uncertainties for which headroom allows will reduce and you will be able to adapt to any changes.

You should provide a clear justification of the assumptions and information used to assess your uncertainties. You should assess the relative contributions clearly showing which uncertainties have the biggest impact in each WRZ. You should communicate this in a clear manner for customers and interested parties to understand easily. You should consider options for reducing uncertainty during the planning period.

South Staffs Water has opted to use the 2002 UKWIR Headroom Methodology for target headroom to assess uncertainty in its South Staffs zone, rather than using risk-based planning or decision-making tools, so there is no risk of double counting uncertainties.

2 Methodology

The methodology for this headroom analysis follows the best practice guidance set out in the 2002 UKWIR “Improved Methodology for Assessing Headroom”. It builds on the headroom analysis models used by South Staffs Water to calculate their target headroom for previous WRMPs.

2.1 Overview

In 2002, UKWIR published its improved methodology for the calculation of headroom allowances. This advocates the use of a probabilistic approach, based on Monte Carlo analysis. The analysis involves defining probability distributions for magnitude of headroom components and combining these to give an overall probability distribution for the target headroom allowance. A “lotus notes”-based spreadsheet with an add-in Monte Carlo analysis tool called @RISK was produced as part of the project.

2.2 Components of Headroom Uncertainty

The 2002 UKWIR methodology Headroom is divided into the following supply side and demand side components:

Table 2: Supply and Demand Side Headroom Categories

| Supply Side Headroom Categories | Demand Side Headroom Categories |
|---|---|
| S1 – Vulnerable surface water licences | D1 – Accuracy of sub-component data |
| S2 – Vulnerable groundwater licences | D2 – Demand forecast variation |
| S3 – Time limited licences | D3 – Uncertainty of climate change on demand |
| S4 – Bulk transfers | D4 – Uncertainty of demand management solutions |
| S5 – Gradual pollution causing a reduction in abstraction | |
| S6 – Accuracy of supply side data | |
| S8 – Uncertainty of climate change on yield | |
| S9 – Uncertain output of new resource developments | |

Source: UKWIR

The 2002 UKWIR methodology removed issue S7 (single source dominance and critical periods) as it was considered to be an outage issue and already included in the supply demand balance. The following two headroom components were added:

- S9 Uncertain output of new resource developments
- D4 Uncertain outcome of demand management measures

Each of the above components has been considered by South Staffordshire Water for its Company water resource zone and the headroom uncertainty issues associated with each component have been identified. For some of the components listed above, more than one issue has been included.

2.2.1 Supply Side Components

S1-S3 (vulnerable licences): Uncertainty over future reductions in abstraction licensing have been updated to include the latest deployable output and abstraction licence values (S1-S3 are only used for sensitivity analysis and are not included in target headroom).

An allowance for S4, bulk transfers, has been introduced at PR19, after better understanding of the uncertainty in company bulk exports.

S5, gradual pollution of groundwater sources, is applied to allow for uncertainty associated with deterioration, rehabilitation and replacement of boreholes, uncertainty in future long-term trends in nitrate pollution, and uncertainty over coalfield mine water pollution at Moors Gorse. Temporary losses of DO relating to these factors are quantified and accounted for in the Outage allowance.

S6 comprises uncertainty in the accuracy of supply-side data. For every groundwater source, the constraining factor for DO is identified: abstraction licence, infrastructure, pumping water level (potential yield), treatment capacity or water quality. For abstraction licences, the uncertainty relates to meter reading reliability. To avoid double-counting, only meters measuring abstraction separately to distribution input are included here. Infrastructure constraints carry uncertainty in pump outputs, yield constraints are subject to a number of uncertainties in the “source reliable output” method, but no such sources exist for South Staffs. There are uncertainties in a number of treatment processes, and water quality can limit deployable output subject to uncertainty in existing conditions (primarily sand ingress here). Trend uncertainty is covered under S5. Surface water yield uncertainty is due to imperfect climate and hydrological historical data records and variability in surface water yield models.

Uncertainty of climate change on source yield (S8), is quantified using Aquator modelling of climate change scenarios on the DO of surface water sources. No groundwater sources are constrained by potential yield, such that there is no risk of climate change impacting groundwater source yield.

No new options are planned for completion in the near future, such that in S9, only final preferred options need be considered. These should not feature in baseline target headroom, but uncertainty in their output could be determined as necessary for any options selected in the final preferred balance.

Supply side components have been updated to include the latest deployable output values reviewed for the draft WRMP.

Sign convention for supply-side headroom follows that of UKWIR 2002, that is:

- Data uncertainty that leads to a loss of *Deployable Output* = negative Headroom
- Data uncertainty that leads to an increase in *Demand* = positive Headroom

2.2.2 Demand Side Components

D1 accounts for uncertainty in the accuracy of sub-component data. As for S6, this reflects the reliability of meter readings, which could impact the accuracy of the demand forecast. To avoid double-counting, only meters measuring distribution input separately to abstraction are included here.

D2 comprises uncertainty in population growth, change in size of households, measured and unmeasured consumption, non-household consumption, dry-year correction, and peak period adjustment. These are input as time series of % uncertainty to the model.

D3, uncertainty of impact of climate change on demand has been determined according to the UKWIR methodology, Impact of Climate Change on Water Demand (2013), with time series of % uncertainty applied to household consumption.

D4, uncertainty of demand management solutions, has not been included in baseline target headroom. Should demand management solutions be required to maintain the supply demand balance to 2045, an allowance will be made in final preferred target headroom for D4.

Sign convention for demand-side headroom follows that of UKWIR 2002, that is:

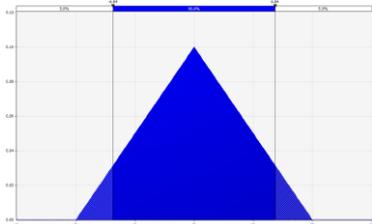
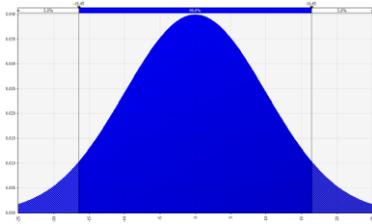
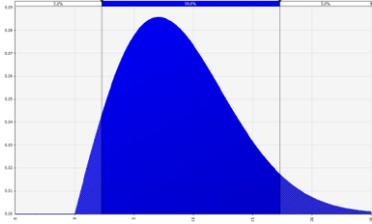
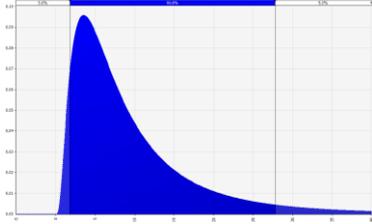
- Data uncertainty that leads to a decrease in *Demand* = negative Headroom
- Data uncertainty that leads to an increase in *Demand* = positive Headroom

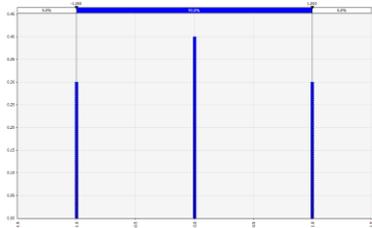
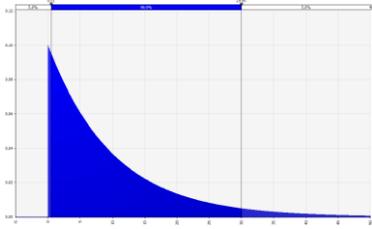
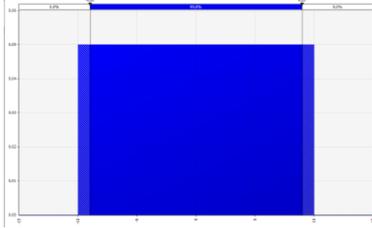
Each of the components of headroom is described in more detail in the following sections.

2.3 Probability Distributions and Monte Carlo Simulation

For each issue, a probability distribution has been developed that quantifies the extent of the uncertainty. A variety of distributions is available within the methodology, with triangular distribution being the most commonly used. Distributions have been used depending upon the individual circumstances with examples presented in Table 3.

Table 3: The Types of Probability Distribution that can be used for Headroom Analysis

| Type | Shape | Description | Application |
|------------|---|---|---|
| Triangular |  | Most easily defined continuous distribution. Defined by a least likely, most likely & maximum likely value. Can be skewed either way. | Situations where the value can be any value within a range and the most likely value can be estimated. Widely applicable, though may not be appropriate if highly skewed. |
| Normal |  | Symmetrical continuous distribution defined by a mean and standard deviation. | Most commonly applied situations where the probability of the extreme values of the distribution would artificially increase if using a triangular distribution. |
| Weibull |  | Continuous distribution. | Difficult to define but could be fitted to a data set within the software. |
| Log-normal |  | Skewed continuous distribution defined by a mean and standard deviation. | Situations where there is a large difference between the maximum and the most likely values such that a triangular distribution is considered unsuitable. |

| Type | Shape | Description | Application |
|--------------------|--|--|---|
| Discrete |  | Non-continuous distribution defined by values and probabilities. | Situations where specific values apply and values in between do not. |
| Exponential |  | Continuous distribution. | Suitable for extreme events but with the introduction of cut-offs. Difficult to define but could be fitted to a data set within the software. |
| Fixed |  | Continuous distribution defined by a single value. | Situations where only one value applies. Essentially not a distribution but given as an option within the software. |

The Monte Carlo simulation combines each of the individual component distributions to produce an overall distribution of headroom uncertainty. This is achieved by running a large number of trials (or iterations). In each trial values are randomly selected from within the component distributions and summed to give an overall headroom value for the trial. After a large number of trials (ten thousand has been used in this analysis) a distribution of headroom values results. To take account of changing uncertainty throughout the planning period the analysis has been repeated on an annual basis between 2017/18 to 2044/45. Key issues identified during the analysis, together with the results are presented below for each resource zone.

2.3.1 Software and simulations

Various software packages are available for performing Monte Carlo analysis. This methodology has been tested using @RISK, an add-in software package which operates within a spreadsheet environment. When a Monte Carlo simulation is run, the software randomly selects numbers from the probability distribution assigned to each component of target headroom. Each set of random numbers effectively simulates a single 'what-if' scenario for the spreadsheet model. As the simulation runs, the model is recalculated for each scenario and the results are presented as a series of forecast charts for Headroom Uncertainty.

The simulation stops according to criteria set by the user, which is normally a number of iterations or trials. The number of trials must be set to give an acceptable mean standard error for the simulation results, whilst controlling the processing time to workable limits. A typical number of trials might be 1,000 to 10,000.

3 Headroom Components

The South Staffs Water headroom model has been developed following the best-practice UKWIR methodology, and builds on previous iterations used for WRMP14 and WRMP09.

3.1 Supply Components

3.1.1 S1.1 Vulnerable Surface Water Licences

Headroom uncertainty associated with vulnerable surface water licences arises from concerns over the sustainability of abstractions at the licensed rates and the likelihood that licences may be modified (reduced). Where appropriate, this has been considered under scenario modelling for the draft plan.

3.1.2 S2.1 Vulnerable Groundwater Licences

The EA has an aspiration to reduce groundwater abstraction licences in many catchments as part of their Restoring Sustainable Abstraction Programme. For many catchments the licence clawback has now been quantified through the CAMS process, and this has resulted in a significantly lower licensable resource (with much greater potential licence reductions). The driver in future for clawing back licences will be the Water Framework Directive, however there are no quantitative numbers available yet. This has been considered under scenario modelling for the draft plan.

3.1.3 S3.1 Time-limited Licences

The Company has three time-limited licences:

Table 4: Time-limited licence quantities and dates

| Licence | Time Limited Quantity (Annual Average MI/d) | Time Limit Date |
|--------------------------------|--|-----------------|
| River Severn (18/54/2/584/S) | 11 | 31st March 2034 |
| 3/28/6/84/S and 3/28/6/99/S | 50 | 30th March 2018 |
| Blakedown 3 (18/54/6/140/G) | 2 (0) | 31st March 2021 |

Part of the River Severn licence (No. 584) is time limited to 2034 (11 MI/d). This abstraction is from the River Severn. The River Blithe licence is scheduled to alter abstracted volumes in 2018, however new licenced volumes will still exceed infrastructure capacity. This means the licence change after 2018 has no impact on peak transfer capacities. However, the deployable output is strongly linked to a clause allowing use of the River Trent licence to maintain River Blithe flows above the Hands-Off Flow for the River Blithe.

Abstraction from the Blakedown 3 borehole is for the purpose of augmenting water levels in the nearby pools and rivers and is neither used for public water supply nor affects the operation of other boreholes

Overall, no allowance for time-limited licence is to be made in headroom. These are all to be assessed in scenarios.

3.1.4 S4 Bulk Supplies

The Company operates around 30 potable water connections at the boundaries of its supply area which together constitute a net export of potable water. The majority of these are small in nature and are known collectively as the Minor Exports. There is a much larger export to Severn Trent Water in the Wolverhampton area which arises from the joint ownership by South Staffs Water and Severn Trent Work of the River Severn abstraction.

The capacity of Minor Exports is up to 5 MI/d but average usage has been consistently around 1 MI/d and is largely independent of seasonal demands. Nevertheless, volumes have increased on occasion to 2 MI/d during the peak demand months. As a consequence, a positive headroom value of 1 MI/d is specified.

The contractual entitlement for the Wolverhampton Export is 40.6 MI/d at average and 48 MI/d at peak and has been adopted for the Company’s deployable output calculations. Whilst the peak capacity is proven and has been assumed by Severn Trent Water in its planning assumptions, the annual average volume is not taken and Severn Trent have indicated that their modelling assumptions only allow for 36 MI/d. However, it has been agreed with the Environment Agency that 40.6 MI/d should be assumed by both companies for planning purposes, with no allowance for uncertainty in headroom.

Table 5: SSW Bulk Supply Agreements and Uncertainty

| | Annual Average (MI/d) | Peak Week (MI/d) | | Minimum Uncertainty (MI/d) | Maximum Uncertainty (MI/d) |
|---------------|-----------------------|------------------|------------|----------------------------|----------------------------|
| Minor Exports | 1.0 | 1.0 | Triangular | Avg 0.0 Peak 0.0 | Avg 0.0 Peak +1.0 |

3.1.5 S5 Gradual Groundwater Pollution

The effects of a gradual or sudden pollution event can have a significant impact on deployable output. Where this results in a long-term loss of deployable output then this should be included in headroom. Three areas of uncertainty have been identified by South Staffs Water under this category.

3.1.5.1 Physical Deterioration of Boreholes

The asset condition and performance of each borehole has been regularly undertaken since PR09. This assessment has underpinned significant increases in investment under asset maintenance in the Company’s groundwater sites. The average age of the Company’s boreholes is more than 75 years and without this investment, significant borehole failures are likely, resulting in a reduction in deployable output. Whilst it is assumed that sufficient capital maintenance work will be funded and carried out to maintain stable serviceability, experience has shown that losses in deployable output arise in two ways:

- Asset performance, as measured by water quality (sand and turbidity), will decline to such an extent that outputs are cut back. Whilst short term reductions in output are accounted for in the Company’s outage allowance, a significant reduction in permanent output may be incurred for a number of years pending site enabling works. Moreover, when re-drilling is required, there may be further delays for the drilling, testing and licencing process; and also, the requirement to construct new pump houses and connecting pipelines to existing treatment and network.

- Where remedial or replacement work is undertaken, there is a risk that yields will be lower or water quality may be different, with a resulting impact on deployable output.

Factors, Likelihood and Magnitude

The available evidence at SSW suggests that physical deterioration of boreholes can be divided into three main categories, and each remedial option is associated with some risk.

1. Deterioration of solid casing causing ingress of poor quality water. Subsequent relining can cause additional drawdown and a reduction in yield, or relining may not be practical causing a reduction in source output if the borehole is filled
2. Chemical and/or biological encrustation & clogging of slotted casing and open-hole sections, causing increased drawdown or water quality problems, with potential loss of yield. Chemical or mechanical treatment may cause deterioration in raw water quality.
3. Collapse and/or erosion of sandstone borehole walls, causing turbidity and requiring a drop in pumping rate, with potential loss of yield. Re-drilling or relining can cause additional drawdown and a reduction in yield. Re-drilling can however allow an increase in yield, particularly at peak.

The following assumptions have been used in evaluating the risk from borehole works in headroom:

- The maximum groundwater deployable output that currently could be affected is 140 MI/d (80% of peak total groundwater D.O.).
- When each source is relined or replaced, there is a 10% chance that the yield will be reduced by 10%.
- When the borehole is replaced, there is a 5% chance that peak DO is increased by 20%.
- Over the first 20 years this represents a 10% chance of a total loss of 14 MI/d offset by a 5% chance of a total increase of 28 MI/d (peak). This level of investment and hence risk is assumed to continue over the remainder of the planning period.

The following discrete distribution was applied for each year for both annual average and peak week:

Table 6: Physical Deterioration of Boreholes: Headroom distributions

| | Average | Peak |
|---------------|-----------|----------|
| Minimum Loss | -1.4 MI/d | 0 MI/d |
| Median Loss | 0 MI/d | 0 MI/d |
| Maximum Loss | 0.67 MI/d | 0.7 MI/d |
| Probability 1 | 5% | |
| Probability 2 | 85% | 90% |
| Probability 3 | 10% | 10% |

3.1.5.2 S5/2 Nitrate, Pesticide and Solvent contamination

From the point of view of headroom, uncertainty in future long-term trends in nitrate and other groundwater contaminants has the potential to impact D.O. through a need for additional treatment and associated losses. Any output failures due to short term or seasonal peaks in nitrate are captured in company outage allowance.

Based on nitrate trends, the Company has identified a risk that some sources and existing blends (e.g. ASPW, CHPW1 and KIPW1) may exceed the nitrate limit during and after AMP7. The potential D.O. loss is based on the following assumptions.

Only a small proportion of the output of each station would be treated to a sufficiently low nitrate level to allow this to blend with the remainder of the source output, to bring the overall nitrate level below the required standard. There will be 2% losses associated with the treated component.

A triangular distribution has been applied to both annual average and peak week headroom, as the treatment plant would treat the same amount of water under both scenarios. The risk increases incrementally over time.

Table 7: Nitrate and other groundwater contamination: annual increases in headroom components from 2020

| | Average | Peak Week |
|--------------|-----------|-----------|
| Minimum Loss | 0 MI/d | 0 MI/d |
| Most Likely | 0.05 MI/d | 0.1 MI/d |
| Maximum Loss | 0.15 MI/d | 0.25 MI/d |

The uncertainty around nitrate treatment has been added with a starting point of 2020 in the headroom model.

3.1.5.3 S5/3 Mine waters

Available evidence suggests that there is a small risk that the Moors Gorse groundwater source could be contaminated by rising mine water, following the cessation of remedial pumping from the underlying coalfield.

Factors, Likelihood and Magnitude

Following the review of groundwater deployable outputs for the FWRMP, the dry year deployable output of Moors Gorse for the purposes of the headroom model is 2.7 MI/d at average and peak based on likely NEP outcomes. A discrete distribution has been applied to these values, which assumes a small probability (5%) that the total deployable output from the source will be lost.

Table 8: Mine water headroom distributions

| | For annual average | | For peak week | |
|--------------|--------------------|-------------|---------------|-------------|
| | Volume MI/d | Probability | Volume MI/d | Probability |
| Minimum Loss | 0 | 95% | 0 | 95% |
| Maximum Loss | 2.7 | 5% | 2.7 | 5% |

3.1.6 S6 Accuracy of Supply-side Data: Groundwater

Data inaccuracy or lack of information can be a significant source of uncertainty around the calculation of deployable output. We have examined the constraining factors which define the Company's deployable output figures and assessed the range of uncertainty around each of these.

3.1.6.1 Abstraction Licence Constraints

The table below summarises the groundwater source deployable outputs that are constrained by abstraction licence, and whether the source has separate abstraction and distribution input meters. Where there are separate meters then the potential metering error has been estimated and is used as a measure of the uncertainty in the deployable output figures.

A figure of +/-2% is assumed for metering uncertainty. Where the abstraction meter and the distribution input meter are one and the same, then no uncertainty is attributed to the deployable output as this uncertainty would be double counted in the demand components of headroom.

Table 9: Abstraction licence-constrained sources: D.O. and meter uncertainty status

| Source | Dry Year Deployable Output affected MI/d | Peak Week Deployable Output affected MI/d | Separate abstraction and distribution input meter |
|--|--|---|---|
| SLPW | 5 | 5 | No |
| MGPW | 2.7 | 2.7 | No |
| SEPW | 5 | N/A | No |
| MBPW | 8.5 | N/A | No |
| ASPW | 18 | N/A | No |
| COPW | 15 | N/A | No |
| PRPW | 20 | N/A | No |
| MAPW1 | 0.5 | N/A | No |
| SHPW | 0 | N/A | Yes |
| SOPW | 0 | N/A | No |
| LHPW1 | 5 | N/A | Yes |
| PHPW1 | 12 | N/A | Yes |
| TVPW | 13 | N/A | No |
| FRPW | 10 | 12 | Yes |
| CHPW1 | 6 | N/A | yes |
| Total | 120.7 | 19.7 | |
| Total (separate abstraction meters only) | 40.7 | 12.0 | |

This uncertainty has been applied using a triangular distribution

Table 10: Abstraction licence-constrained sources: headroom distribution for metering inaccuracy

| | Annual Average | Peak Week |
|---------------------------|----------------|------------|
| Minimum Loss (gain in DO) | -0.81 MI/d | -0.24 MI/d |
| Best Estimate | 0 MI/d | 0 MI/d |
| Maximum Loss (loss in DO) | +0.81 MI/d | +0.24 MI/d |

3.1.6.2 Infrastructure (Pump Capacity) Constraints

The table below summarises the groundwater source deployable outputs that are constrained by pumping capacity.

Table 11: Infrastructure (pump capacity)-constrained sources D.O.

| Source | Average Deployable Output affected MI/d | Peak Week Deployable Output affected MI/d |
|--------|---|---|
| COPW | N/A | 18.0 |
| ASPW | N/A | 18.0 |
| MAPW1 | N/A | 0.52 |
| Total | 0.0 | 36.5 |

An overall uncertainty around pumping capacity has been derived from the detailed breakdown. This is +/- 5%. This uncertainty has been applied using a triangular distribution

Table 12: Infrastructure (pump capacity)-constrained sources: headroom distribution

| | Annual Average | Peak Week |
|---------------------------|----------------|------------|
| Minimum Loss (gain in DO) | 0 MI/d | -1.83 MI/d |
| Best Estimate | 0 MI/d | 0 MI/d |
| Maximum Loss (loss in DO) | 0 MI/d | +1.83 MI/d |

3.1.6.3 Pumping Water Level

No sources are constrained by potential yield.

3.1.6.4 Treatment Capacity

The following sources are constrained by treatment works capacity:

Table 13: Treatment-constrained sources D.O.

| Source | Average Deployable Output affected MI/d | Peak Week Deployable Output affected MI/d |
|---------------------|---|---|
| GW PRPW1 | N/A | 20.08 |
| GW HIPW1 | 5.0 | 5.0 |
| GW LHPW1 | N/A | 5.0 |
| PHPW | N/A | 12.0 |
| CCPW1 | N/A | 6.0 |
| SW Central WTW | N/A | 110.0 |
| SW River Severn WTW | N/A | 207.8 |
| Total | GW 5.0 SW 0.0 | GW 48.0 SW 317.8 |

Operational staff have confirmed that the range of uncertainty around groundwater treatment processes is small and so the Company has assumed a +/- 2% figure in headroom. The following range of uncertainty proposed is based on a triangular distribution:

Table 14: Treatment-constrained sources: headroom distribution

| Groundwater | Annual Average | Peak Week |
|---------------------------|----------------|------------|
| Minimum Loss (gain in DO) | -0.10 MI/d | -0.96 MI/d |
| Best Estimate | 0 MI/d | 0 MI/d |
| Maximum Loss (loss in DO) | +0.10 MI/d | +0.96 MI/d |

3.1.6.5 Water Quality (Sand Pumping)

Five sources are constrained by sand production (causing excessive turbidity). The relevant constraints are identified below:

Table 15: Water quality-constrained sources D.O.

| Source | Average Deployable Output affected in MI/d | Peak Week Deployable Output affected in MI/d | Range in DO |
|--------|--|--|-------------|
| CRPW1 | 5.5 | 5.5 | +2%/-10% |
| MBPW | N/A | 9.0 | +2%/-10% |
| HOPW | 2.5 | 2.5 | +2%/-10% |
| SEPW | N/A | 5.0 | +2%/-10% |
| TVPW | N/A | 15 | +2%/-10% |
| Total | 8.0 | 37.0 | +2%/-10% |

The proposed headroom uncertainty for water quality (sand pumping) is a triangular function as follows:

Table 16: Water quality-constrained sources: headroom distribution

| | Annual Average | Peak Week |
|---------------------------|----------------|------------|
| Minimum Loss (gain in DO) | -0.16 MI/d | -0.74 MI/d |
| Best Estimate | 0 MI/d | 0 MI/d |
| Maximum Loss (loss in DO) | +0.80 MI/d | +3.7 MI/d |

3.1.7 Accuracy of data for surface water yields

The modelling of deployable output from surface water sources is dependent upon the accuracy of hydrological records and the uncertainty around the derived river flows from catchment models. The Company has two surface water sources, the River Severn and Blithfield Reservoir, and the yield of these sources is modelled within the water resources model Aquator.

3.1.7.1 The River Severn (River Severn WTW)

The deployable output of River Severn is constrained by the river flow at Bewdley, storage at Clywedog, and by the status of River Regulation (releases from Clywedog Reservoir and the Shropshire Groundwater Scheme). These parameters are modelled by Severn Trent Water using the regional AQUATOR model, and the output is used as a constraint in the SSW Aquator model.

UKWIR guidance (ref 02/WR/13/2, p.29) suggests that the accuracy of river flow data derived from catchment models is +/- 10 to 20%. In addition to data accuracy, the models used may not fully represent the catchments. On this basis, the total uncertainty around the catchment modelling is assumed to be at the lower end +/-10%, given the extensive work carried out this AMP, although the impact on deployable outputs may be somewhat lower than this.

The dry year annual D.O. at River Severn is dependent on catchment modelling of inflows to Clywedog reservoir, and inflows to the catchments on the Severn upstream of Bewdley. Data and modelling uncertainty could impact on the 'reliable yield' of River Severn during River

Regulation. We have retained the assumptions agreed with the Environment Agency for the PR09 FWRMP of +/- 5.0% for the range of error in dry year annual deployable output.

Given the complex range of constraints, a pragmatic approach has been taken with an uncertainty range of +/- 5% around the modelled average DO value of 118.5 MI/d (excluding Wolverhampton bulk export). This equates to +/- 5.9 MI/d.

The peak week D.O. is largely constrained by treatment capacity. For River Severn, the same 2% uncertainty applies to this as for groundwater sites.

3.1.7.2 Blithfield Reservoir

The inflow from the Upper River Blithe directly affects reservoir storage levels, and hence deployable output. The total uncertainty around the catchment modelling is again assumed to be +/-15% and this has been confirmed by sensitivity testing of the Blithfield HYSIM models during refinement of the Aquator model. The range of uncertainty around the dry year annual D.O. (58.72 MI/d) is therefore estimated at +/- 10% or +/- 5.9 MI/d.

The peak week D.O. is largely influenced by the treatment works capacity (see Section S6/1 above). For Central Works, the treatment processes are such that a larger uncertainty of 9% is appropriate.

The proposed headroom uncertainty is a triangular function as follows:

Table 17: Surface Water Yields: Headroom Distributions

| | Annual Average | Peak Week |
|---------------------------|----------------|-------------|
| Minimum Loss (gain in DO) | -11.8 MI/d | -14.06 MI/d |
| Best Estimate | 0 MI/d | 0 MI/d |
| Maximum Loss (loss in DO) | +11.8 MI/d | 14.06 MI/d |

3.1.8 S8 Uncertainty of Climate Change on Deployable Output

The modelling approach used to determine the impact of climate change on deployable output is described under separate cover.

The wet and dry climate change scenarios modelled in the Aquator model represent the range of uncertainty around the mid-range scenario up to 2080. The range of uncertainty used in the headroom assessment is based on the difference between the corrected wet/dry scenarios and mid-range scenarios, as shown in the following table.

Table 18: Modelled uncertainty in D.O. resulting from climate change impacts on yield

| Scenarios at 2085 | Base D.O. (MI/d) | Mid-Range Estimate | Range of Uncertainty by 2085 (Wet) (MI/d) | Range of Uncertainty by 2085 (Dry) (MI/d) |
|-------------------|------------------|--------------------|---|---|
| Dry Year | 338 | 317 (-21) | 14 | -19 |
| Peak Week | 419.1 | 393.1 (-26) | 17.4 | -23.6 |

The wet and dry uncertainty has been extrapolated up to 2045 as a time-varying series in the headroom model, using the scale factors set down in Section 3.3.6 of the Environment Agency's water resources planning guidelines (2012).

Table 19: Climate Change Uncertainty in Deployable Output

| Scenarios at 2045 | Base D.O. (MI/d) | Mid-Range Estimate | Range of Uncertainty by 2045 (Wet) (MI/d) | Range of Uncertainty by 2045 (Dry) (MI/d) |
|-------------------|------------------|--------------------|---|---|
| Dry Year | 338 | 328.5 (-9.5) | 6.3 | -8.6 |
| Peak Week | 419.1 | 407.3 (-11.8) | 7.8 | -10.7 |

This uncertainty range has been incorporated into both dry year annual average and peak week headroom by assuming a triangular distribution with the upper and lower limits defined by the wet and dry scenario results. The mid-range estimate is assumed to be zero but the correction is incorporated within the baseline forecast. As the wet year case produces an increase in DO it is treated as negative headroom and the dry year case vice versa.

3.1.9 S9 Uncertain output of new resource developments

South Staffs Water have no new resources due to be commissioned in their baseline supply/demand forecast. Any new resources selected as options in the preferred plan will have an uncertainty allowance in DO assigned to the final preferred headroom values.

3.2 Demand Components

3.2.1 D1/1 Accuracy of sub-component data

Potential errors in the measurement of distribution input are an important component of headroom and are accounted for here. Only errors on meters which measure distribution input separately to abstraction are accounted for, otherwise there would be a double count because abstraction (metering) error is identified under S6/1.

The Company has assumed an equal accuracy measurement of +/- 2% over the planning period. This will not be altered by subsequent meter replacements. Those distribution input meters that are separate from the source meters are listed in the following table.

Table 20: Source Deployable Output and Distribution Input Meter Status

| SOURCE NAME | PR14 Annual Average D.O. (MI/d) | PR14 Peak Week D.O. (MI/d) | Separate Distribution input meter |
|-------------|---------------------------------|----------------------------|-----------------------------------|
| SMPW | 5.0 | 5.0 | Yes |
| MGPW | 2.7 | 2.7 | Yes |
| SEPW | 5.0 | 5.0 | Yes |
| MBPW | 8.5 | 9.0 | No |
| CRPW1 | 5.5 | 5.5 | Yes |
| CHPW1 | 10.0 | 10.0 | No |
| COPW | 15.0 | 18.0 | No |
| KIPW1 | 9.0 | 9.0 | No |
| PRPW1 | 20.0 | 20.0 | No |
| ASPW | 18.0 | 18.0 | No |
| HIPW | 5.6 | 5.6 | No |
| MAPW1 | 0.52 | 0.52 | No |
| HOPW | 2.45 | 2.45 | No |
| SHPW | 0.0 | 0.0 | Yes |
| SOPW | 0.0 | 0.0 | Yes |
| BVPW | 4.8 | 4.8 | No |

| SOURCE NAME | PR14 Annual Average D.O. (MI/d) | PR14 Peak Week D.O. (MI/d) | Separate Distribution input meter |
|----------------------------------|---------------------------------|----------------------------|-----------------------------------|
| LHPW1 | 5.0 | 5.0 | Yes |
| SSPW | 0.0 | 0.0 | Yes |
| PHPW | 12.0 | 12.0 | Yes |
| TVPW | 13.7 | 15.0 | Yes |
| FRPW | 10 | 12 | Yes |
| CCPW1 | 6.5 | 6.6 | Yes |
| Total groundwater DO | 157.9 | 165.6 | |
| Total GW DO separate DI meters | 51.3 | 55.6 | |
| River Severn Works | 118.5 | 159.0 | Yes |
| Central Works | 58.7 | 91.3 | Yes |
| Total surface water DO | 177.2 | 250.3 | |
| Total DO | 372.9 | 457.9 | |
| Total DO with separate DI meters | 228.5 | 305.9 | |

The total DO with separate DI meters is less than the demand forecast at DYAA and DYCP across planning period; therefore, headroom uncertainty is constant. A triangular distribution based an uncertainty of +/- 2% is applied as follows:

Table 21: Distribution Input Meter Accuracy: Headroom Distribution

| | Annual Average | Peak Week |
|---------------------------------------|----------------|-----------|
| Minimum Headroom (decrease in demand) | -4.6 MI/d | -6.1 MI/d |
| Best Estimate | 0 MI/d | 0 MI/d |
| Maximum Headroom (increase in demand) | +4.6 MI/d | +6.1 MI/d |

3.2.2 D2/1 Demand Forecasting Uncertainty

This element of headroom accounts for the uncertainty around the forecasts of individual demand components. Uncertainty must be estimated on the normal year forecasts as the dry year adjustment is added on to the normal year demand as an aggregate figure at the end. In order to account for any additional uncertainty resulting from the dry year adjustment this is included as well.

Components have been included for population, housing growth, measured and unmeasured demand and leakage as well as the switching forecast. Uncertainty in the peak demand forecast and in the dry year factor used in the annual average demand forecast have also been considered. The headroom approach for each component of the demand forecast is described below.

- Household Consumption: Uncertainty in population, growth in number of properties, measured and unmeasured per capita consumption, household growth, number of meter optants and dry year adjustment has been assessed and compiled into a single set of values for upper and lower bounds, input to the model as a triangular distribution centred on the baseline forecast. For the population and properties uncertainty, we apply the UKWIR guideline errors to a normal distribution. Modelling error was accounted for using normally distributed regression coefficients (an assumption consistent with using ordinary

least squares as the best linear unbiased estimator). The overall Household Consumption uncertainty is +/-13.22Ml/d by 2045 for DYAA conditions, and +18 Ml/d to -19.1 Ml/d by 2045 for DYCP conditions.¹

- **Non-Household Consumption:** Uncertainty around non-household consumption is estimated to be +/-5.06 Ml/d by 2045. This range was determined by looking at the range of different forecasts that were derived from different trend analyses and or linear models (with economic variables) and taking the mean/median and standard deviation of the distribution of these forecasts.¹
- **Leakage:** Uncertainty around leakage has been determined as +/-5% of target leakage. This equates to +/-3.4 Ml/d in 2018, decreasing to +/-2.9 Ml/d by 2045: a triangular distribution has been used accordingly. This is consistent with work on SELL for the business plan.
- There are also uncertainties surrounding predicted peak consumption volumes used in the supply demand balance. This is because dry years do not occur regularly and the predicted demands do not always coincide with supply shortfalls. Review of historic data was used to define a triangular distribution between +/- 10 Ml/d for uncertainty in critical period uplift factor.

For each year the uncertainties for each consumption category are added together within the headroom model to give an overall uncertainty for the demand forecasts. The percentages are calculated from demand excluding SPL and MUR. The table below demonstrates the size of the demand component for key years in the forecast.

Table 22: Total Demand Headroom Annual Average 5 yearly intervals

| Annual Average | 2019/20 | 2024/25 | 2029/30 | 2034/35 | 2039/40 | 2044/45 |
|---------------------------------------|---------|---------|---------|---------|---------|---------|
| Minimum Headroom (decrease in demand) | -7.12 | -10.67 | -13.85 | -16.33 | -18.77 | -21.21 |
| Best Estimate | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Maximum Headroom (increase in demand) | 7.12 | 10.67 | 13.85 | 16.33 | 18.77 | 21.21 |

The approach to assessing the demand component for peak week headroom uncertainty is the same as that for annual average except that the dry year adjustment component is replaced with that for since peak week volume uncertainty.

Table 23: Total Demand Headroom Peak Week 5 yearly intervals

| Peak Week | 2019/20 | 2024/25 | 2029/30 | 2034/35 | 2039/40 | 2044/45 |
|---------------------------------------|---------|---------|---------|---------|---------|---------|
| Minimum Headroom (decrease in demand) | -17.33 | -24.33 | -30.24 | -32.37 | -34.71 | -37.11 |
| Best Estimate | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Maximum Headroom (increase in demand) | 15.83 | 19.68 | 23.81 | 27.90 | 31.96 | 35.99 |

3.2.3 Uncertainty of impact of Climate Change on Demand

The impact of climate change on demand was previously assessed using the techniques developed in the UKWIR study, Impact of Climate Change on Demand. This has used statistical analyses performed on PCC data from Thames Water and Severn Trent Water to

¹ Artesia Consulting (2018) SST & CAM uncertainty D2-D3 outputs 2018-08-07.xls

generate regression models relating demand to climatic data. These models have been used in combination with UKCP09 climate projections to derive algorithms and look-up tables for each UK region.

The Company has selected the Severn Trent water model as it better simulates the water using behaviour of the South Staffs customer base. It has used probability data on increase in demand in the South Humber region as this geographically matches the majority of its supply area. The data tables contain forecast values for the percentage increase in household consumption and these have been directly applied using Company average PCC values on an annual basis.

The table below shows the range of uncertainty associated with the forecast annual average impact of climate change on demand. All impacts are scaled to a mid-value of zero to avoid double counting the base CC demand impacts (which are included in baseline demand). Probability data have been used to produce a triangular distribution.

Table 24: Climate Change Demand Uncertainty Annual Average: 5 yearly Headroom

| Annual Average | 2019/20 | 2024/25 | 2029/30 | 2034/35 | 2039/40 | 2044/45 |
|-------------------|---------|---------|---------|---------|---------|---------|
| P10 Headroom MI/d | 0.07 | 0.31 | 0.55 | 0.79 | 1.03 | 1.31 |
| P50 Headroom MI/d | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| P90 Headroom MI/d | -0.07 | -0.24 | -0.44 | -0.62 | -0.82 | -1.01 |

Table 25: Climate Change Demand Uncertainty Peak Week: 5 yearly Headroom

| Peak Week | 2019/20 | 2024/25 | 2029/30 | 2034/35 | 2039/40 | 2044/45 |
|-------------------|---------|---------|---------|---------|---------|---------|
| P10 Headroom MI/d | 0.34 | 1.23 | 2.14 | 3.10 | 4.09 | 5.08 |
| P50 Headroom MI/d | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| P90 Headroom MI/d | -0.24 | -0.85 | -1.52 | -2.21 | -2.89 | -3.59 |

3.3 Analysing the data

Once the distributions are selected, they are built into the @Risk model. The model is then run for 10,000 iterations to produce the combined headroom. The in-built sensitivity functions are used to analyse which inputs have the greatest impact on the result.

4 Results and conclusions

4.1 Target Headroom Results

4.1.1 DYAA

The results of the target headroom modelling under dry year average conditions are shown in Figure 1 below. A full table of results by percentile is presented in Appendix A. The chosen risk profile is also shown. Target headroom starts at 7.0 MI/d in 2018, increasing steadily along the 95th percentile profile to a maximum of 9.9 MI/d in 2030. The increase in risk acceptance beyond 2030 means that target headroom decreases slowly thereafter to 7.8 MI/d by 2045.

Figure 1: DYAA Target Headroom Results and chosen risk profile

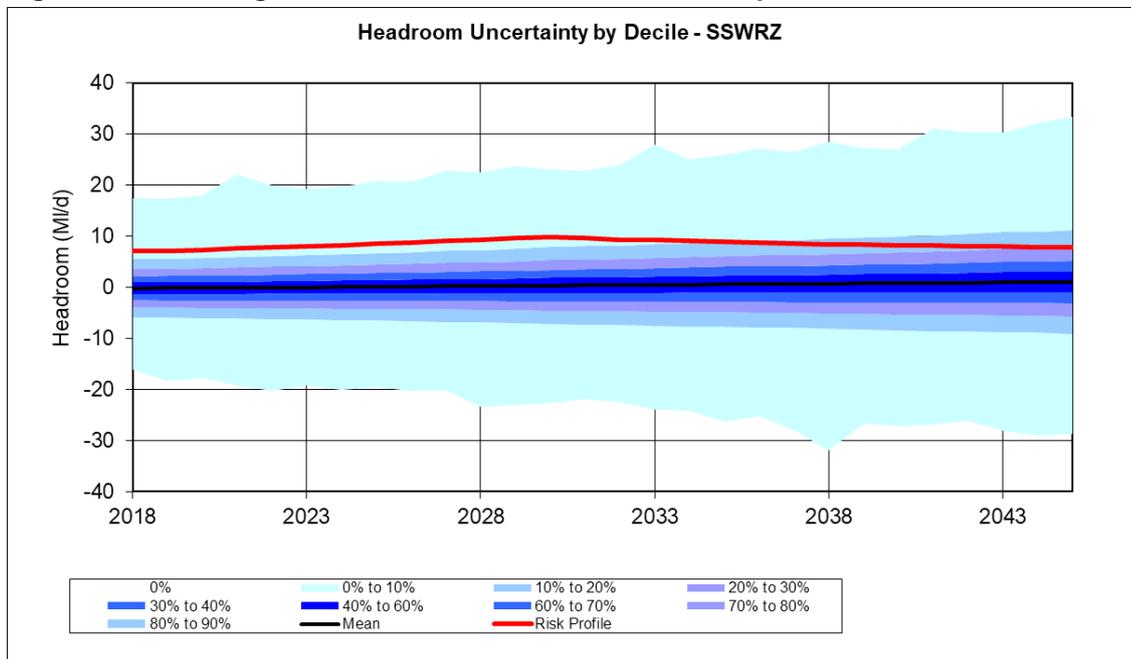
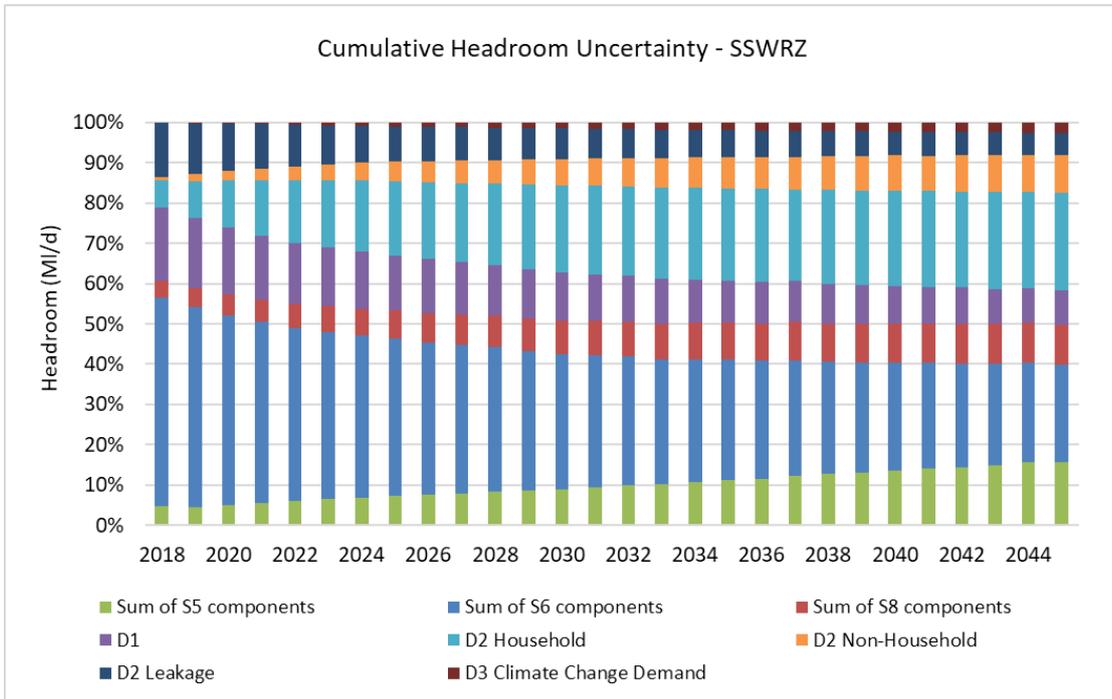


Figure 2 shows the proportional breakdown of target headroom by component for the selected risk profile. In the early years, uncertainty is dominated by S6 supply-side uncertainty, especially relating to potential yield of surface water sources. There is some demand uncertainty as a result of potential distribution input meter inaccuracy. As time progresses, uncertainty relating to demand increases steadily as a proportion of overall headroom, with accompanying proportional increases in supply-side climate change and groundwater contamination uncertainty.

Figure 2: % Breakdown of DYAA Target Headroom by sub-component



4.1.2 DYCP

The results of the target headroom modelling under dry year critical period conditions are shown in Figure 3 below. A full table of results by percentile is presented in Appendix A. The chosen risk profile is also shown. Target headroom starts at 11.6 Ml/d in 2018, increasing steadily along the 95th percentile profile to a maximum of 13.7 Ml/d in 2030. The increase in risk acceptance beyond 2030 means that target headroom fluctuates slightly thereafter, finishing at 12.8 Ml/d by 2045.

Figure 3: DYCP Target Headroom Results and chosen risk profile

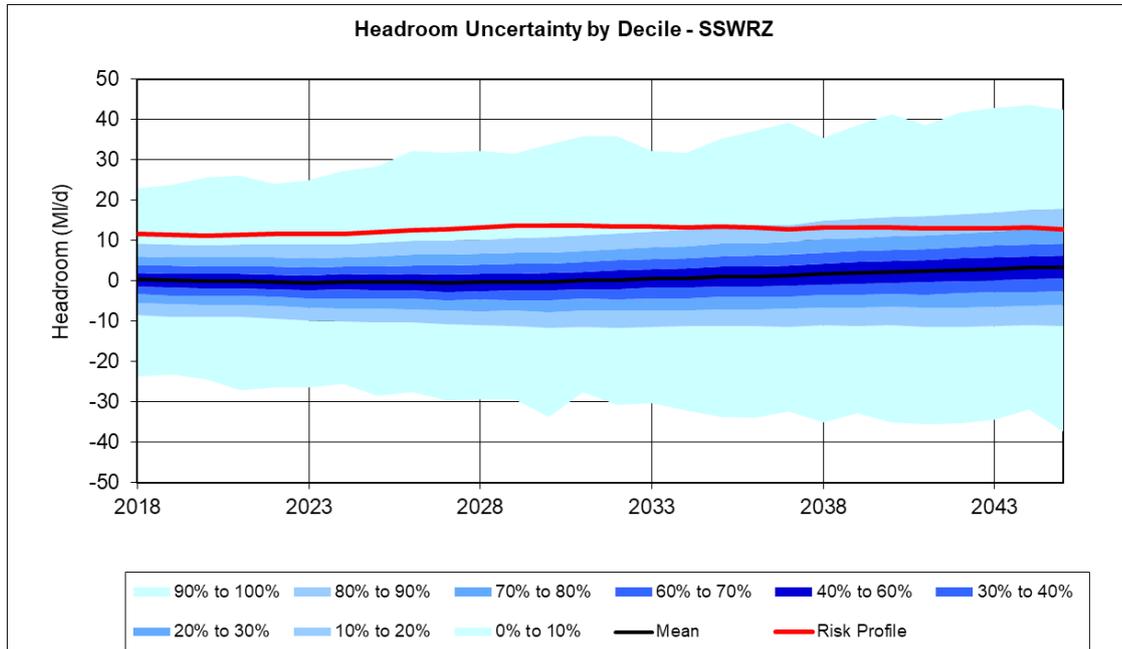
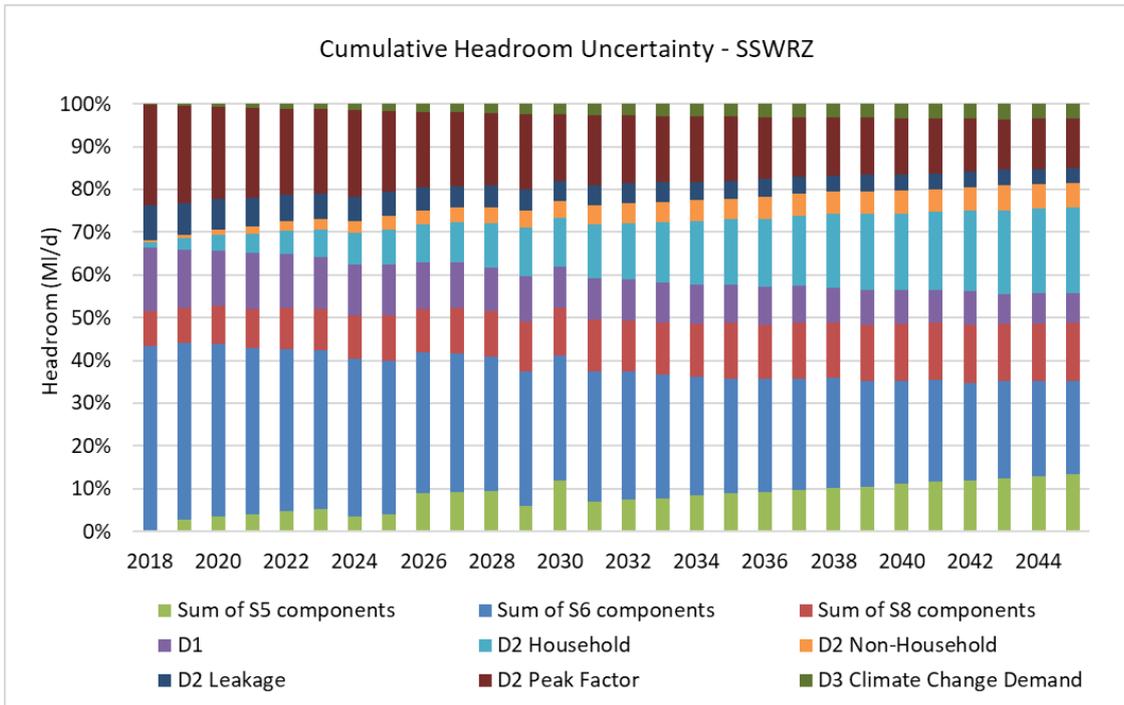


Figure 4 shows the proportional breakdown of target headroom by component for the selected risk profile. In the early years, uncertainty is dominated by S6 supply-side uncertainty, especially relating to potential yield of surface water sources. There is some demand uncertainty as a result of potential distribution input meter inaccuracy. As time progresses, uncertainty relating to demand increases steadily as a proportion of overall headroom, with accompanying proportional increases in supply-side climate change and groundwater contamination uncertainty.

Figure 4: % Breakdown of DYCP Target Headroom by sub-component



4.2 Chosen Risk Profile

The headroom values for the chosen risk profile for each year of the planning period and the corresponding percentiles, both for DYAA and DYCP / Peak are summarised in the tables below. South Staffordshire Water is accepting a higher level of risk in the future than at present which is expected as, over time, aspects of uncertainty included in headroom will be resolved.

Table 26: Headroom values in MI/d and corresponding %iles for the chosen risk profile (DYAA)

| Year | DYAA Headroom (all components) | DYAA (%ile) | DYAA Headroom (climate change components) |
|-----------|--------------------------------|-------------|---|
| 2017 / 18 | 7.05 | 95% | 0.30 |
| 2018 / 19 | 7.19 | 95% | 0.36 |
| 2019 / 20 | 7.29 | 95% | 0.40 |
| 2020 / 21 | 7.56 | 95% | 0.45 |
| 2021 / 22 | 7.82 | 95% | 0.52 |
| 2022 / 23 | 7.96 | 95% | 0.57 |
| 2023 / 24 | 8.26 | 95% | 0.62 |
| 2024 / 25 | 8.57 | 95% | 0.69 |
| 2025 / 26 | 8.75 | 95% | 0.75 |
| 2026 / 27 | 9.01 | 95% | 0.80 |
| 2027 / 28 | 9.22 | 95% | 0.86 |
| 2028 / 29 | 9.61 | 95% | 0.92 |
| 2029 / 30 | 9.91 | 95% | 0.99 |
| 2030 / 31 | 9.58 | 94% | 0.98 |
| 2031 / 32 | 9.30 | 93% | 0.98 |
| 2032 / 33 | 9.21 | 92% | 1.00 |
| 2033 / 34 | 9.06 | 91% | 1.00 |
| 2034 / 35 | 8.90 | 90% | 1.00 |
| 2035 / 36 | 8.75 | 89% | 1.01 |
| 2036 / 37 | 8.53 | 88% | 1.00 |
| 2037 / 38 | 8.45 | 87% | 0.99 |
| 2038 / 39 | 8.40 | 86% | 1.02 |
| 2039 / 40 | 8.19 | 85% | 1.00 |
| 2040 / 41 | 8.10 | 84% | 1.01 |
| 2041 / 42 | 8.07 | 83% | 1.02 |
| 2042 / 43 | 8.03 | 82% | 1.02 |
| 2043 / 44 | 7.78 | 81% | 0.99 |
| 2044 / 45 | 7.77 | 80% | 1.00 |

Table 27: Headroom values in MI/d and corresponding %iles for the chosen risk profile (DYCP / Peak)

| Year | DYCP / Peak Headroom (all components) | DYCP / Peak (%ile) | DYCP Headroom (climate change components) |
|-----------|---------------------------------------|--------------------|---|
| 2017 / 18 | 11.57 | 95% | 0.94 |
| 2018 / 19 | 11.28 | 95% | 0.93 |
| 2019 / 20 | 11.26 | 95% | 1.02 |
| 2020 / 21 | 11.47 | 95% | 1.10 |
| 2021 / 22 | 11.54 | 95% | 1.19 |
| 2022 / 23 | 11.64 | 95% | 1.20 |
| 2023 / 24 | 11.63 | 95% | 1.28 |
| 2024 / 25 | 12.04 | 95% | 1.41 |
| 2025 / 26 | 12.50 | 95% | 1.42 |
| 2026 / 27 | 12.67 | 95% | 1.53 |
| 2027 / 28 | 13.23 | 95% | 1.60 |
| 2028 / 29 | 13.62 | 95% | 1.79 |
| 2029 / 30 | 13.73 | 95% | 1.74 |
| 2030 / 31 | 13.74 | 94% | 1.92 |
| 2031 / 32 | 13.50 | 93% | 1.91 |
| 2032 / 33 | 13.37 | 92% | 1.92 |
| 2033 / 34 | 13.13 | 91% | 1.93 |
| 2034 / 35 | 13.48 | 90% | 2.07 |
| 2035 / 36 | 13.13 | 89% | 1.99 |
| 2036 / 37 | 12.75 | 88% | 2.00 |
| 2037 / 38 | 13.22 | 87% | 2.05 |
| 2038 / 39 | 13.17 | 86% | 2.06 |
| 2039 / 40 | 13.19 | 85% | 2.12 |
| 2040 / 41 | 12.94 | 84% | 2.11 |
| 2041 / 42 | 13.06 | 83% | 2.17 |
| 2042 / 43 | 12.91 | 82% | 2.14 |
| 2043 / 44 | 13.21 | 81% | 2.15 |
| 2044 / 45 | 12.83 | 80% | 2.12 |

4.3 Risk Profile Sensitivity

The range in target headroom between 15th and 85th percentiles is shown below. Full tables of results for DYAA and DYCP are presented in Appendix A.

Table 28: Difference between 15%ile and 85%iles in 2017/18 and 2044/45

| Scenario | 15-%ile (2017 / 18) | 85-%ile (2017 / 18) | 15-%ile (2044 / 45) | 85-%ile (2044 / 45) |
|-------------|---------------------|---------------------|---------------------|---------------------|
| DYAA | -4.75 | 4.40 | -7.22 | 9.31 |
| DYCP (Peak) | -6.87 | 7.46 | -8.47 | 15.15 |

Appendices

| | | |
|----|--|----|
| A. | Target Headroom Uncertainty Results Tables | 30 |
|----|--|----|

A. Target Headroom Uncertainty Results Tables

Table 29: DYAA Target Headroom Percentiles by Year

| Percentiles | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 |
|-------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 0% | -16.021 | -16.130 | -18.309 | -17.718 | -19.268 | -20.368 | -19.104 | -20.045 | -19.513 | -20.225 | -20.179 | -23.382 | -22.966 | -22.599 | -21.988 | -22.481 | -23.901 | -24.163 | -26.306 | -25.264 | -27.960 | -32.002 | -26.724 | -27.250 | -26.795 | -26.097 | -28.087 | -29.031 | -28.683 |
| 1% | -10.618 | -10.129 | -11.058 | -10.625 | -11.205 | -11.005 | -11.206 | -11.436 | -11.634 | -11.917 | -12.078 | -12.463 | -12.684 | -13.044 | -13.326 | -13.538 | -13.806 | -14.110 | -14.119 | -14.363 | -14.533 | -15.100 | -15.321 | -15.446 | -15.878 | -16.040 | -16.446 | -16.507 | -16.895 |
| 2% | -9.592 | -9.020 | -9.241 | -9.482 | -9.643 | -9.799 | -9.888 | -10.143 | -10.299 | -10.540 | -10.749 | -11.076 | -11.259 | -11.520 | -11.766 | -11.899 | -12.198 | -12.492 | -12.490 | -12.720 | -12.908 | -13.323 | -13.508 | -13.747 | -14.028 | -14.053 | -14.412 | -14.616 | -14.908 |
| 3% | -8.962 | -8.334 | -8.463 | -8.742 | -8.854 | -9.018 | -9.095 | -9.319 | -9.462 | -9.698 | -9.711 | -10.145 | -10.330 | -10.520 | -10.719 | -10.876 | -11.140 | -11.489 | -11.424 | -11.629 | -11.788 | -12.342 | -12.504 | -12.790 | -12.852 | -13.242 | -13.333 | -13.682 | -13.882 |
| 4% | -8.499 | -7.791 | -7.949 | -8.234 | -8.244 | -8.491 | -8.491 | -8.749 | -8.854 | -9.067 | -9.067 | -9.456 | -9.598 | -9.779 | -9.983 | -10.169 | -10.385 | -10.678 | -10.651 | -10.835 | -10.973 | -11.278 | -11.484 | -11.720 | -11.822 | -12.299 | -12.392 | -12.706 | -12.906 |
| 5% | -8.099 | -7.356 | -7.486 | -7.725 | -7.779 | -7.952 | -7.984 | -8.176 | -8.291 | -8.524 | -8.613 | -8.886 | -8.993 | -9.197 | -9.376 | -9.523 | -9.756 | -10.022 | -10.022 | -10.183 | -10.280 | -10.548 | -10.791 | -10.976 | -11.174 | -11.205 | -11.497 | -11.604 | -11.892 |
| 6% | -7.726 | -6.996 | -7.093 | -7.296 | -7.361 | -7.519 | -7.587 | -7.749 | -7.851 | -8.024 | -8.161 | -8.421 | -8.489 | -8.687 | -8.858 | -8.985 | -9.214 | -9.452 | -9.472 | -9.604 | -9.696 | -9.944 | -10.193 | -10.355 | -10.523 | -10.688 | -10.858 | -11.058 | -11.197 |
| 7% | -7.412 | -6.660 | -6.749 | -6.945 | -7.003 | -7.139 | -7.209 | -7.351 | -7.423 | -7.629 | -7.740 | -7.989 | -8.044 | -8.228 | -8.402 | -8.544 | -8.734 | -8.951 | -8.967 | -9.101 | -9.204 | -9.412 | -9.664 | -9.811 | -9.940 | -10.023 | -10.244 | -10.342 | -10.590 |
| 8% | -7.120 | -6.339 | -6.453 | -6.658 | -6.684 | -6.797 | -6.893 | -7.071 | -7.152 | -7.359 | -7.471 | -7.697 | -7.731 | -7.938 | -8.106 | -8.126 | -8.318 | -8.502 | -8.508 | -8.668 | -8.730 | -8.966 | -9.161 | -9.311 | -9.462 | -9.526 | -9.716 | -9.801 | -10.056 |
| 9% | -6.857 | -6.079 | -6.171 | -6.299 | -6.384 | -6.505 | -6.571 | -6.773 | -6.833 | -6.918 | -7.038 | -7.237 | -7.291 | -7.455 | -7.643 | -7.742 | -7.923 | -8.093 | -8.105 | -8.241 | -8.296 | -8.497 | -8.708 | -8.842 | -8.903 | -9.074 | -9.239 | -9.306 | -9.577 |
| 10% | -6.616 | -5.829 | -5.923 | -6.017 | -6.110 | -6.217 | -6.283 | -6.379 | -6.452 | -6.609 | -6.738 | -6.937 | -6.950 | -7.123 | -7.285 | -7.388 | -7.572 | -7.716 | -7.730 | -7.875 | -7.925 | -8.095 | -8.301 | -8.400 | -8.482 | -8.627 | -8.718 | -8.872 | -9.142 |
| 11% | -6.399 | -5.595 | -5.685 | -5.780 | -5.850 | -5.954 | -6.025 | -6.114 | -6.176 | -6.318 | -6.450 | -6.607 | -6.655 | -6.820 | -6.980 | -7.066 | -7.238 | -7.349 | -7.378 | -7.500 | -7.574 | -7.738 | -7.906 | -8.042 | -8.209 | -8.242 | -8.416 | -8.462 | -8.731 |
| 12% | -6.199 | -5.395 | -5.452 | -5.544 | -5.606 | -5.709 | -5.785 | -5.859 | -5.909 | -6.059 | -6.177 | -6.321 | -6.371 | -6.530 | -6.660 | -6.739 | -6.922 | -7.024 | -7.044 | -7.161 | -7.243 | -7.392 | -7.548 | -7.682 | -7.855 | -8.023 | -8.065 | -8.326 | -8.596 |
| 13% | -6.004 | -5.163 | -5.243 | -5.315 | -5.380 | -5.485 | -5.549 | -5.627 | -5.658 | -5.807 | -5.907 | -6.037 | -6.093 | -6.257 | -6.364 | -6.446 | -6.614 | -6.713 | -6.700 | -6.846 | -6.912 | -7.041 | -7.201 | -7.316 | -7.473 | -7.516 | -7.673 | -7.674 | -7.942 |
| 14% | -5.822 | -4.955 | -5.036 | -5.105 | -5.167 | -5.271 | -5.323 | -5.394 | -5.426 | -5.566 | -5.660 | -5.783 | -5.843 | -5.989 | -6.097 | -6.158 | -6.317 | -6.404 | -6.438 | -6.550 | -6.609 | -6.745 | -6.875 | -6.974 | -7.128 | -7.177 | -7.345 | -7.322 | -7.589 |
| 15% | -5.643 | -4.753 | -4.844 | -4.909 | -4.973 | -5.048 | -5.105 | -5.188 | -5.215 | -5.323 | -5.423 | -5.537 | -5.605 | -5.732 | -5.834 | -5.897 | -6.049 | -6.131 | -6.162 | -6.255 | -6.317 | -6.455 | -6.575 | -6.679 | -6.803 | -6.853 | -7.012 | -6.989 | -7.218 |
| 16% | -5.477 | -4.573 | -4.654 | -4.723 | -4.785 | -4.852 | -4.900 | -4.986 | -5.017 | -5.100 | -5.195 | -5.294 | -5.383 | -5.499 | -5.597 | -5.649 | -5.780 | -5.867 | -5.896 | -5.976 | -6.043 | -6.172 | -6.285 | -6.370 | -6.488 | -6.545 | -6.688 | -6.679 | -6.900 |
| 17% | -5.310 | -4.386 | -4.476 | -4.539 | -4.600 | -4.654 | -4.699 | -4.782 | -4.801 | -4.895 | -4.974 | -5.073 | -5.158 | -5.264 | -5.355 | -5.403 | -5.518 | -5.608 | -5.627 | -5.724 | -5.777 | -5.892 | -5.986 | -6.087 | -6.188 | -6.247 | -6.378 | -6.370 | -6.557 |
| 18% | -5.156 | -4.229 | -4.306 | -4.371 | -4.420 | -4.462 | -4.523 | -4.582 | -4.600 | -4.691 | -4.764 | -4.869 | -4.955 | -5.129 | -5.171 | -5.278 | -5.366 | -5.451 | -5.530 | -5.582 | -5.697 | -5.750 | -5.863 | -5.959 | -6.059 | -6.159 | -6.259 | -6.250 | -6.437 |
| 19% | -5.005 | -4.078 | -4.137 | -4.200 | -4.252 | -4.282 | -4.339 | -4.393 | -4.406 | -4.500 | -4.568 | -4.661 | -4.729 | -4.902 | -4.941 | -5.048 | -5.131 | -5.127 | -5.188 | -5.276 | -5.328 | -5.441 | -5.537 | -5.637 | -5.737 | -5.837 | -5.937 | -5.928 | -6.115 |
| 20% | -4.857 | -3.912 | -3.973 | -4.037 | -4.083 | -4.107 | -4.163 | -4.209 | -4.217 | -4.298 | -4.361 | -4.459 | -4.532 | -4.685 | -4.724 | -4.821 | -4.891 | -4.888 | -4.944 | -5.000 | -5.056 | -5.169 | -5.255 | -5.355 | -5.455 | -5.555 | -5.655 | -5.646 | -5.833 |
| 21% | -4.705 | -3.760 | -3.823 | -3.875 | -3.916 | -3.936 | -3.985 | -4.038 | -4.035 | -4.103 | -4.172 | -4.263 | -4.327 | -4.485 | -4.507 | -4.597 | -4.658 | -4.661 | -4.715 | -4.783 | -4.844 | -4.959 | -5.045 | -5.145 | -5.245 | -5.345 | -5.445 | -5.436 | -5.623 |
| 22% | -4.563 | -3.605 | -3.668 | -3.716 | -3.759 | -3.776 | -3.814 | -3.874 | -3.861 | -3.927 | -3.989 | -4.081 | -4.132 | -4.226 | -4.275 | -4.303 | -4.382 | -4.441 | -4.455 | -4.485 | -4.559 | -4.623 | -4.709 | -4.803 | -4.903 | -4.999 | -5.005 | -5.192 | -5.140 |
| 23% | -4.424 | -3.457 | -3.519 | -3.569 | -3.602 | -3.619 | -3.641 | -3.701 | -3.693 | -3.753 | -3.814 | -3.886 | -3.938 | -4.032 | -4.064 | -4.173 | -4.227 | -4.248 | -4.260 | -4.341 | -4.391 | -4.456 | -4.542 | -4.633 | -4.640 | -4.746 | -4.674 | -4.861 | -4.810 |
| 24% | -4.292 | -3.316 | -3.370 | -3.419 | -3.452 | -3.460 | -3.477 | -3.535 | -3.528 | -3.580 | -3.646 | -3.702 | -3.751 | -3.855 | -3.868 | -3.904 | -3.968 | -4.010 | -4.032 | -4.048 | -4.123 | -4.173 | -4.236 | -4.347 | -4.394 | -4.396 | -4.482 | -4.417 | -4.600 |
| 25% | -4.161 | -3.178 | -3.222 | -3.279 | -3.313 | -3.311 | -3.323 | -3.385 | -3.370 | -3.416 | -3.478 | -3.531 | -3.561 | -3.663 | -3.675 | -3.700 | -3.760 | -3.813 | -3.836 | -3.842 | -3.902 | -3.947 | -4.011 | -4.109 | -4.164 | -4.155 | -4.240 | -4.171 | -4.349 |
| 26% | -4.031 | -3.049 | -3.093 | -3.136 | -3.165 | -3.158 | -3.222 | -3.216 | -3.251 | -3.304 | -3.357 | -3.409 | -3.439 | -3.500 | -3.507 | -3.559 | -3.615 | -3.625 | -3.682 | -3.709 | -3.735 | -3.788 | -3.888 | -3.922 | -3.931 | -4.000 | -3.937 | -4.110 | -4.040 |
| 27% | -3.910 | -2.916 | -2.956 | -2.994 | -3.018 | -3.012 | -3.019 | -3.066 | -3.057 | -3.080 | -3.139 | -3.194 | -3.233 | -3.333 | -3.333 | -3.373 | -3.424 | -3.433 | -3.448 | -3.496 | -3.531 | -3.574 | -3.631 | -3.651 | -3.709 | -3.637 | -3.810 | -3.740 | -3.889 |
| 28% | -3.793 | -2.789 | -2.816 | -2.854 | -2.871 | -2.874 | -2.914 | -2.902 | -2.920 | -2.979 | -3.032 | -3.086 | -3.127 | -3.127 | -3.159 | -3.202 | -3.240 | -3.240 | -3.251 | -3.288 | -3.324 | -3.357 | -3.424 | -3.444 | -3.502 | -3.430 | -3.603 | -3.533 | -3.682 |
| 29% | -3.676 | -2.672 | -2.699 | -2.736 | -2.753 | -2.756 | -2.796 | -2.784 | -2.802 | -2.861 | -2.914 | -2.968 | -3.009 | -3.009 | -3.041 | -3.084 | -3.122 | -3.122 | -3.133 | -3.170 | -3.206 | -3.239 | -3.306 | -3.326 | -3.384 | -3.312 | -3.485 | -3.415 | -3.564 |
| 30% | -3.559 | -2.555 | -2.582 | -2.619 | -2.636 | -2.639 | -2.679 | -2.667 | -2.685 | -2.744 | -2.797 | -2.851 | -2.892 | -2.892 | -2.924 | -2.967 | -3.005 | -3.005 | -3.016 | -3.053 | -3.089 | -3.122 | -3.189 | -3.209 | -3.267 | -3.195 | -3.368 | -3.298 | -3.447 |
| 31% | -3.442 | -2.438 | -2.465 | -2.502 | -2.519 | -2.522 | -2.562 | -2.550 | -2.568 | -2.627 | -2.680 | -2.734 | -2.775 | -2.775 | -2.807 | -2.850 | -2.888 | -2.888 | -2.899 | -2.936 | -2.972 | -3.005 | -3.072 | -3.092 | -3.150 | -3.078 | -3.251 | -3.181 | -3.330 |
| 32% | -3.325 | -2.321 | -2.348 | -2.385 | -2.402 | -2.405 | -2.445 | -2.433 | -2.451 | -2.510 | -2.563 | -2.617 | -2.658 | -2.658 | -2.690 | -2.733 | -2.771 | -2.771 | -2.782 | -2.819 | -2.855 | -2.888 | -2.955 | -2.975 | -3.033 | -2.961 | -3.134 | -3.064 | -3.213 |
| 33% | -3.208 | -2.204 | -2.231 | -2.268 | -2.285 | -2.288 | -2.328 | -2.316 | -2.334 | -2.393 | -2.446 | -2.500 | -2.541 | -2.541 | -2.573 | -2.616 | -2.654 | -2.654 | -2.665 | -2.702 | -2.738 | -2.771 | -2.838 | -2.858 | -2.916 | -2.844 | -3.017 | -2.947 | -3.096 |
| 34% | -3.091 | -2.087 | -2.114 | -2.151 | -2.168 | -2.171 | -2.211 | -2.199 | -2.217 | -2.276 | -2.329 | -2.383 | -2.424 | -2.424 | -2.456 | -2.499 | -2.537 | -2.537 | -2.548 | -2.585 | -2.621 | -2.654 | -2.721 | -2.741 | -2.799 | -2.727 | -2.900 | -2.830 | -2.979 |
| 35% | -2.974 | -1.970 | -1.997 | -2.034 | -2.051 | -2.054 | -2.094 | -2.082 | -2.100 | -2.159 | -2.212 | -2.266 | -2.307 | -2.307 | -2.339 | -2.382 | -2.420 | -2.420 | -2.431 | -2.468 | -2.504 | -2.537 | -2.604 | -2.624 | -2.682 | -2.610 | -2.783 | -2.713 | -2.862 |
| 36% | -2.857 | -1.853 | -1.880 | -1.917 | -1.934 | -1.937 | -1.977 | -1.965 | -1.983 | -2.042 | -2.095 | -2.149 | -2.190 | -2.190 | -2.222 | -2.265 | -2.303 | -2.303 | -2.314 | -2.351 | -2.387 | -2.420 | -2.487 | -2.507 | -2.565 | -2.493 | -2.666 | -2.596 | -2.745 |
| 37% | -2.740 | -1.736 | -1.763 | -1.800 | -1.817 | -1.820 | -1.860 | -1.848 | -1.866 | -1.925 | -1.978 | -2.032 | -2.073 | -2.073 | -2.105 | -2.148 | -2.186 | -2.186 | -2.197 | -2.234 | -2.270 | -2.303 | -2.370 | -2.390 | -2.448 | -2.376 | -2.549 | -2.479 | -2.628 |
| 38% | -2.623 | -1.619 | -1.646 | -1.683 | -1.699 | -1.702 | -1.742 | -1.730 | -1.748 | -1.807 | -1.860 | -1.914 | -1.955 | -1.955 | -1.987 | -2.030 | -2.068 | -2.068 | -2.079 | -2.116 | -2.152 | -2.185 | -2.252 | -2.272 | -2.330 | -2.258 | -2.431 | -2.361 | - |

Table 30: DYCP Target Headroom Percentiles by Year

| Percentile | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 | 2041 | 2042 | 2043 | 2044 | 2045 |
|------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 0% | -17.076 | -23.770 | -23.385 | -24.414 | -27.093 | -26.512 | -26.568 | -25.656 | -28.485 | -27.671 | -29.699 | -29.332 | -29.471 | -33.694 | -27.491 | -30.739 | -30.278 | -32.118 | -33.829 | -33.954 | -32.385 | -34.997 | -32.738 | -35.068 | -35.458 | -35.362 | -34.337 | -31.945 | -37.261 |
| 1% | -11.076 | -14.318 | -15.247 | -15.908 | -16.376 | -16.747 | -16.829 | -17.501 | -17.564 | -18.067 | -18.892 | -18.992 | -20.277 | -20.581 | -20.508 | -20.919 | -20.712 | -20.520 | -20.749 | -21.185 | -21.337 | -21.443 | -21.999 | -21.604 | -21.895 | -22.368 | -22.920 | -22.412 | -22.468 |
| 2% | -10.011 | -13.089 | -13.767 | -14.200 | -14.217 | -14.770 | -15.231 | -15.684 | -15.538 | -16.011 | -16.962 | -17.072 | -18.357 | -18.075 | -18.001 | -18.428 | -18.425 | -18.768 | -18.671 | -18.790 | -19.347 | -18.942 | -19.291 | -19.773 | -19.480 | -19.773 | -19.291 | -19.688 | -19.688 |
| 3% | -9.238 | -11.949 | -12.784 | -12.919 | -13.137 | -13.752 | -14.231 | -14.381 | -14.338 | -14.839 | -15.706 | -15.865 | -16.398 | -16.768 | -16.648 | -17.179 | -17.124 | -17.648 | -17.508 | -17.619 | -18.176 | -17.782 | -18.124 | -18.696 | -18.364 | -18.696 | -18.124 | -18.586 | -18.586 |
| 4% | -8.739 | -11.264 | -11.882 | -12.229 | -12.214 | -12.779 | -13.374 | -13.512 | -13.444 | -14.032 | -14.838 | -15.120 | -15.679 | -15.939 | -15.879 | -16.390 | -16.326 | -16.848 | -16.708 | -16.819 | -17.376 | -17.082 | -17.424 | -17.996 | -17.664 | -17.996 | -17.424 | -17.916 | -17.916 |
| 5% | -8.185 | -10.558 | -11.259 | -11.361 | -11.496 | -12.085 | -12.603 | -12.779 | -12.828 | -13.255 | -13.760 | -13.927 | -14.262 | -14.885 | -14.529 | -14.914 | -14.561 | -14.583 | -14.650 | -14.713 | -15.167 | -14.810 | -14.903 | -15.359 | -15.027 | -15.359 | -14.810 | -15.250 | -15.250 |
| 6% | -7.735 | -10.038 | -10.778 | -10.708 | -10.859 | -11.368 | -12.066 | -12.184 | -12.245 | -12.466 | -12.961 | -13.345 | -13.497 | -14.112 | -13.731 | -13.966 | -13.740 | -13.873 | -13.779 | -13.862 | -14.159 | -13.935 | -13.952 | -14.424 | -14.120 | -14.424 | -13.935 | -14.341 | -14.341 |
| 7% | -7.403 | -9.658 | -10.132 | -10.278 | -10.387 | -10.798 | -11.438 | -11.573 | -11.667 | -12.100 | -12.610 | -12.300 | -12.734 | -13.524 | -13.133 | -13.062 | -13.172 | -13.049 | -13.093 | -13.103 | -13.403 | -13.108 | -13.076 | -13.576 | -13.272 | -13.576 | -13.108 | -13.474 | -13.474 |
| 8% | -7.030 | -9.200 | -9.694 | -9.860 | -9.855 | -10.204 | -10.872 | -10.964 | -11.183 | -11.359 | -11.779 | -12.166 | -12.287 | -12.956 | -12.466 | -12.822 | -12.502 | -12.538 | -12.463 | -12.412 | -12.671 | -12.490 | -12.312 | -12.280 | -12.699 | -12.727 | -12.530 | -12.341 | -12.341 |
| 9% | -6.686 | -8.736 | -9.314 | -9.437 | -9.460 | -9.797 | -10.300 | -10.470 | -10.687 | -10.920 | -11.331 | -11.667 | -11.802 | -12.377 | -11.902 | -12.230 | -11.993 | -11.897 | -11.827 | -11.820 | -12.089 | -11.748 | -11.682 | -11.619 | -12.116 | -12.026 | -11.841 | -11.648 | -11.648 |
| 10% | -6.396 | -8.396 | -8.923 | -9.046 | -9.042 | -9.416 | -9.884 | -10.070 | -10.220 | -10.434 | -10.881 | -11.119 | -11.275 | -11.766 | -11.360 | -11.584 | -11.547 | -11.308 | -11.346 | -11.172 | -11.374 | -11.120 | -11.129 | -10.899 | -11.461 | -11.410 | -11.176 | -10.911 | -11.344 |
| 11% | -6.085 | -8.037 | -8.598 | -8.668 | -8.673 | -9.043 | -9.490 | -9.674 | -9.817 | -10.044 | -10.401 | -10.678 | -10.745 | -11.220 | -10.905 | -11.058 | -10.987 | -10.781 | -10.814 | -10.669 | -10.815 | -10.507 | -10.466 | -10.391 | -10.897 | -10.782 | -10.598 | -10.358 | -10.816 |
| 12% | -5.795 | -7.705 | -8.185 | -8.327 | -8.364 | -8.673 | -9.091 | -9.248 | -9.480 | -9.663 | -9.997 | -10.323 | -10.283 | -10.716 | -10.356 | -10.561 | -10.516 | -10.330 | -10.322 | -10.247 | -10.230 | -9.983 | -10.002 | -9.877 | -10.223 | -10.063 | -9.719 | -10.223 | |
| 13% | -5.586 | -7.426 | -7.847 | -7.993 | -8.054 | -8.342 | -8.820 | -8.914 | -9.076 | -9.313 | -9.592 | -9.870 | -9.833 | -10.323 | -10.051 | -10.069 | -9.886 | -9.875 | -9.731 | -9.800 | -9.535 | -9.543 | -9.478 | -9.741 | -9.741 | -9.563 | -9.202 | -9.563 | |
| 14% | -5.352 | -7.148 | -7.501 | -7.680 | -7.687 | -8.002 | -8.411 | -8.625 | -8.654 | -8.967 | -9.162 | -9.470 | -9.475 | -9.882 | -9.580 | -9.697 | -9.662 | -9.520 | -9.435 | -9.359 | -9.363 | -8.985 | -9.038 | -8.956 | -9.252 | -9.251 | -8.992 | -8.779 | -8.973 |
| 15% | -5.126 | -6.869 | -7.182 | -7.347 | -7.408 | -7.708 | -8.117 | -8.265 | -8.372 | -8.688 | -8.782 | -9.155 | -9.155 | -9.487 | -9.222 | -9.262 | -9.279 | -9.116 | -8.995 | -8.905 | -8.903 | -8.545 | -8.648 | -8.513 | -8.825 | -8.768 | -8.469 | -8.319 | -8.473 |
| 16% | -4.926 | -6.585 | -6.879 | -7.005 | -7.112 | -7.424 | -7.877 | -7.967 | -8.043 | -8.337 | -8.471 | -8.835 | -8.811 | -9.077 | -8.811 | -8.791 | -8.783 | -8.618 | -8.545 | -8.470 | -8.470 | -8.104 | -8.205 | -8.087 | -8.333 | -8.366 | -8.102 | -7.872 | -7.972 |
| 17% | -4.689 | -6.297 | -6.589 | -6.731 | -6.829 | -7.147 | -7.618 | -7.726 | -7.799 | -8.100 | -8.190 | -8.466 | -8.411 | -8.537 | -8.311 | -8.311 | -8.147 | -8.073 | -8.000 | -7.925 | -7.850 | -7.850 | -7.484 | -7.587 | -7.850 | -7.883 | -7.617 | -7.387 | -7.587 |
| 18% | -4.462 | -6.035 | -6.363 | -6.457 | -6.545 | -6.849 | -7.196 | -7.334 | -7.440 | -7.693 | -7.905 | -8.151 | -8.021 | -8.241 | -8.105 | -8.114 | -8.053 | -8.082 | -7.991 | -7.922 | -7.852 | -7.781 | -7.712 | -7.432 | -7.286 | -7.455 | -7.189 | -6.963 | -7.189 |
| 19% | -4.264 | -5.766 | -6.132 | -6.197 | -6.229 | -6.549 | -6.842 | -7.045 | -7.146 | -7.386 | -7.612 | -7.795 | -7.689 | -8.045 | -7.782 | -7.768 | -7.702 | -7.756 | -7.671 | -7.457 | -7.354 | -7.284 | -7.215 | -7.002 | -6.868 | -7.073 | -7.122 | -6.860 | -6.585 |
| 20% | -4.094 | -5.524 | -5.883 | -5.908 | -5.939 | -6.301 | -6.654 | -6.824 | -6.855 | -7.090 | -7.319 | -7.517 | -7.379 | -7.738 | -7.479 | -7.409 | -7.367 | -7.350 | -7.093 | -7.140 | -6.920 | -6.821 | -6.692 | -6.503 | -6.678 | -6.697 | -6.461 | -6.158 | -6.104 |
| 21% | -3.916 | -5.294 | -5.655 | -5.667 | -5.746 | -6.003 | -6.459 | -6.556 | -6.605 | -6.819 | -7.079 | -7.204 | -7.124 | -7.352 | -7.069 | -7.135 | -7.015 | -7.009 | -6.738 | -6.785 | -6.502 | -6.259 | -6.365 | -6.201 | -6.347 | -6.363 | -6.059 | -5.829 | -5.747 |
| 22% | -3.725 | -5.026 | -5.412 | -5.426 | -5.458 | -5.754 | -6.202 | -6.297 | -6.334 | -6.555 | -6.788 | -6.929 | -7.077 | -7.252 | -6.971 | -6.922 | -6.722 | -6.677 | -6.429 | -6.468 | -6.144 | -5.909 | -5.970 | -5.909 | -5.970 | -5.668 | -5.450 | -5.356 | |
| 23% | -3.521 | -4.786 | -5.174 | -5.235 | -5.225 | -5.475 | -5.952 | -6.043 | -6.042 | -6.244 | -6.539 | -6.611 | -6.569 | -6.791 | -6.471 | -6.437 | -6.236 | -6.387 | -6.122 | -6.152 | -5.901 | -5.664 | -5.663 | -5.470 | -5.699 | -5.562 | -5.175 | -5.125 | -4.977 |
| 24% | -3.345 | -4.574 | -4.941 | -5.020 | -4.982 | -5.213 | -5.703 | -5.796 | -5.810 | -6.004 | -6.302 | -6.301 | -6.277 | -6.496 | -6.167 | -6.182 | -6.033 | -6.083 | -5.774 | -5.806 | -5.552 | -5.396 | -5.321 | -5.124 | -5.348 | -5.236 | -4.876 | -4.774 | -4.598 |
| 25% | -3.165 | -4.351 | -4.739 | -4.794 | -4.782 | -4.953 | -5.495 | -5.505 | -5.559 | -5.726 | -6.067 | -6.100 | -6.003 | -6.181 | -5.906 | -5.925 | -5.791 | -5.808 | -5.473 | -5.458 | -5.264 | -5.074 | -4.994 | -4.807 | -5.007 | -4.846 | -4.492 | -4.402 | -4.212 |
| 26% | -2.976 | -4.100 | -4.490 | -4.535 | -4.523 | -4.749 | -5.247 | -5.257 | -5.300 | -5.478 | -5.813 | -5.762 | -5.603 | -5.639 | -5.423 | -5.435 | -5.295 | -5.312 | -4.974 | -4.963 | -4.780 | -4.686 | -4.518 | -4.340 | -4.465 | -4.180 | -3.867 | -3.759 | -3.583 |
| 27% | -2.830 | -3.878 | -4.291 | -4.355 | -4.355 | -4.566 | -5.007 | -5.031 | -5.077 | -5.252 | -5.526 | -5.555 | -5.514 | -5.653 | -5.288 | -5.382 | -5.204 | -5.316 | -4.974 | -4.966 | -4.800 | -4.686 | -4.518 | -4.340 | -4.465 | -4.180 | -3.867 | -3.759 | -3.583 |
| 28% | -2.683 | -3.672 | -4.091 | -4.155 | -4.155 | -4.344 | -4.789 | -4.767 | -4.831 | -5.005 | -5.285 | -5.280 | -5.265 | -5.495 | -5.111 | -5.111 | -4.907 | -4.963 | -4.583 | -4.582 | -4.446 | -4.266 | -4.015 | -3.836 | -4.026 | -3.802 | -3.570 | -3.386 | -3.259 |
| 29% | -2.547 | -3.499 | -3.846 | -3.942 | -3.943 | -4.166 | -4.568 | -4.529 | -4.608 | -4.779 | -5.043 | -5.037 | -5.020 | -5.247 | -4.859 | -4.859 | -4.605 | -4.668 | -4.288 | -4.274 | -4.150 | -3.883 | -3.722 | -3.562 | -3.711 | -3.473 | -3.257 | -3.060 | -2.870 |
| 30% | -2.388 | -3.307 | -3.634 | -3.740 | -3.740 | -3.949 | -4.356 | -4.313 | -4.412 | -4.574 | -4.815 | -4.748 | -4.768 | -4.947 | -4.485 | -4.485 | -4.354 | -4.380 | -4.019 | -3.953 | -3.885 | -3.580 | -3.401 | -3.267 | -3.398 | -3.136 | -2.898 | -2.780 | -2.534 |
| 31% | -2.245 | -3.149 | -3.436 | -3.549 | -3.549 | -3.736 | -4.179 | -4.076 | -4.200 | -4.266 | -4.475 | -4.428 | -4.451 | -4.581 | -4.231 | -4.231 | -4.047 | -4.073 | -3.704 | -3.670 | -3.595 | -3.307 | -3.119 | -2.955 | -3.086 | -2.791 | -2.613 | -2.422 | -2.215 |
| 32% | -2.090 | -2.943 | -3.239 | -3.355 | -3.355 | -3.526 | -3.961 | -3.860 | -3.988 | -4.049 | -4.242 | -4.242 | -4.300 | -4.310 | -3.960 | -3.960 | -3.794 | -3.823 | -3.453 | -3.423 | -3.348 | -3.061 | -2.873 | -2.709 | -2.840 | -2.545 | -2.367 | -2.176 | -1.990 |
| 33% | -1.933 | -2.725 | -3.021 | -3.137 | -3.137 | -3.292 | -3.727 | -3.626 | -3.754 | -3.815 | -4.008 | -4.008 | -4.066 | -4.076 | -3.726 | -3.726 | -3.560 | -3.589 | -3.219 | -3.189 | -3.114 | -2.827 | -2.639 | -2.475 | -2.606 | -2.311 | -2.133 | -1.942 | -1.756 |
| 34% | -1.803 | -2.547 | -2.825 | -2.941 | -2.941 | -3.086 | -3.521 | -3.420 | -3.548 | -3.609 | -3.802 | -3.802 | -3.860 | -3.870 | -3.520 | -3.520 | -3.354 | -3.383 | -2.993 | -2.963 | -2.888 | -2.60 | | | | | | | |

